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*Note:
Not
prior art*

Title of Invention:

Electrode materials for use in resistance welding,
composite electrodes for use in resistance welding
and a process for producing them

Claims:

1. Copper-base electrode material for use in resistance welding which is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders with a total oxygen content of no more than 500 ppm.
2. Copper-base electrode for use in resistance welding which has an oxygen content of no more than 550 ppm and which is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders.
3. Copper-base electrode material for use in resistance welding which is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders with a total oxygen content of no more than 500 ppm, the mixture consisting of 0.3 - 1.5 wt% Cr powder, 0.02 - 0.22 wt% Zr powder, 0.01 - 0.5 wt% Ag powder, 0.1 - 5.0 wt% W powder and the balance Cu powder.

4. Copper-base electrode material for use in resistance welding which has an oxygen content no more than 550 ppm and which is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders, the mixture consisting of 0.3 - 1.5 wt% Cr powder, 0.02 - 0.22 wt% Zr powder, 0.01 - 0.5 wt% Ag powder, 0.1 - 5.0 wt% W powder and the balance Cu powder.

5. A composite electrode for use in resistance welding which comprises a core member made of the copper-based electrode material recited in any one of claims 1 - 4 and a matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, said core member being fitted integrally in the tip of said matrix to make contact with the work.

6. A process for producing a composite electrode for use in resistance welding in which a core member to make contact with the work is fitted integrally in the tip of a matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, which comprises the steps of packing the mixture of powders of claim 1 or 3 into a copper can, evacuating the can, hermetically sealing it to form a billet, extruding the billet by hot isostatic pressing and thereafter applying a solution treatment, annealing and cold drawing to form the core member, inserting said core member into a depression formed in the top of the matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, and combining said core member with the matrix to form an integral mass.

7. An electrode assembly for use in resistance spot welding which comprises a pair of electrodes to be set on a resistance welding machine, one electrode being a composite electrode

comprising a matrix which has a dissimilar electrode material provided integrally in the tip portion which is to make contact with the work, and the other electrode being a single-component electrode with a tip either having a greater radius of curvature than the composite electrode or being flat in shape.

8. The electrode assembly according to claim 7, wherein said one electrode is a composite electrode comprising a core member made of a copper-based electrode material and a matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, said copper-based electrode material being a sinter of a mixture of Cu, Cr, Zr, Ag and W powders with a total oxygen content of no more than 500 ppm, said matrix being fitted integrally in the tip of said matrix to make contact with the work.

9. The electrode assembly according to claim 7, wherein said one electrode is a composite electrode comprising a core member made of a copper-based electrode material and a matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, said copper-based electrode material having an oxygen content of no more than 550 ppm, and being a sinter of a mixture of Cu, Cr, Zr, Ag and W powders, said core member being fitted integrally in the tip of said matrix to make contact with the work.

10. The electrode assembly according to claim 8 or 9, wherein said mixture consists of 0.3 - 1.5 wt% Cr powder, 0.02 - 0.22 wt% Zr powder, 0.01 - 0.5 wt% Ag powder, 0.1 - 5.0 wt% W powder and the balance Cu powder.

Detailed Description of Invention:

Technical Field of the Invention

The present invention relates to a resistance welding technology which involves the application of an electric current between two clamped workpieces. More specifically, the invention relates to an electrode material for use in resistance welding, a composite electrode using said electrode material, a process for producing the composite electrode and a pair of electrodes suitable for use in resistance spot welding.

Prior Art

Large currents are generally applied to the electrodes used in resistance welding processes including resistance spot welding and seam welding. The electrodes not only generate heat by their own resistance but also are exposed to much of the heat generated in the weld; therefore, the ideal electrode material must have high heat resistance, high strength at elevated temperatures, high electrical conductivity and high thermal conductivity. To meet these needs, the conventional electrode materials for use in resistance welding are composed of Cu-Cr or Cu-Cr-Zr alloys. In addition, electrodes have been commercialized that are less likely to be fused to the work and they are made of dispersion strengthened copper alloys having ceramic powders or high-melting point metals added to Cu alloy powders. Further in addition, composite electrodes are known that have such dispersion strengthened copper alloys provided at the tip of an electrode in contact with the work (see, for example, Japanese Patent Public

Disclosure No. 78683/1989 and Japanese Patent Publication No. 24991/1976).

Problems to be Solved by the Invention

Recently, with a view to improving the corrosion resistance of automobile bodies and the like, the use of surface-treated steel sheets such as galvanized steel sheets and steel sheets with organic coatings has increased. If resistance welding is performed on such surface treated steel sheets using the conventional electrode materials (i.e., Cu-Cr alloys and alumina dispersed copper), fusion to the work or the formation of a brittle surface alloy layer occurs during welding thereby shortening the electrode life. Even in the dispersion strengthened copper alloys having ceramic powders or high-melting point metals added to Cu alloy powders, internal cracking occurs or fusion to the work or the formation of a brittle surface alloy layer takes place during welding, again reducing the electrode life.

In resistance spot welding, the workpieces are firmly clamped between electrodes and an electric current is flowed through the assembly instantaneously. If the electrode tip has a small radius of curvature, particularly when it is domed or a truncated cone, it will produce an indentation mark (depression) on the surface of the workpiece sheet, thereby impairing the appearance of the latter. Therefore, if surface properties are important, an electrode with a tip having an increased radius of curvature or a flat tip is used on the workpiece which needs to have satisfactory surface properties.

However, if surface-treated steel sheets are subjected to resistance spot welding with two commercial chromium-copper electrodes placed on opposite sides of the work, one having a tip with an increased radius of curvature or a flat tip and the other having a domed or frustoconical tip, many fusions or sparks occur on the side where the electrode having a domed or frustoconical tip faces the work and the life of that electrode is shortened. Even if a composite electrode which is less likely to fuse to the work is placed on both sides of the work, fusions or shunt marks occur on the side where the electrode with a tip having an increased radius of curvature or a flat tip is placed and this again contributes to a shorter electrode life.

The present invention has been accomplished under these circumstances and has as an object providing an electrode material that is resistant to cracking and fusion and which is less likely to form a brittle alloy layer, thereby improving the life of electrodes used in resistance welding. Another object of the invention is to improve the life of a composite electrode for use in resistance spot welding by suppressing the occurrence of fusions, sparks and shunt marks.

Means for Solving the Problems

The copper-based electrode material for use in resistance welding which is recited in claim 1 is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders with a total oxygen content of no more than 500 ppm and the mixture preferably consists of 0.3 - 1.5 wt% Cr powder, 0.02 - 0.22 wt% Zr powder, 0.01 - 0.5

wt% Ag powder, 0.1 - 5.0 wt% W powder and the balance Cu powder (claim 3). Needless to say, each powder may contain the usual amounts of incidental impurities. The copper-based electrode material for use in resistance welding which is recited in claim 2 has an oxygen content of no more than 550 ppm and is a sinter of a mixture of Cu, Cr, Zr, Ag and W powders and the mixture preferably has the formulation set forth above (claim 4). It should be noted that the proportions of the Cu, Cr, Zr, Ag and W powders in the mixture are equivalent to the contents of the respective ingredients in the sinter. Therefore, the electrode material may well be described as a copper-based sinter that consists of Cu, Cr, Zr, Ag, W and incidental impurities, with an oxygen content of no more than 550 ppm, and which preferably consists of 0.3 - 1.5 wt% Cr, 0.02 - 0.22 wt% Zr, 0.01 - 0.5 wt% Ag, 0.1 - 5.0 wt% W, and the balance being Cu, incidental impurities and no more than 550 ppm of oxygen.

The composite electrode for use in resistance welding which is recited in claim 5 comprises a core member made of the above-specified copper-based electrode material and a matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy, and said core member is fitted integrally in the tip of said matrix to make contact with the work. This composite electrode can be produced efficiently by the process recited in claim 6 which comprises the steps of packing the above-specified mixture of powders into a copper can, evacuating the can, hermetically sealing it to form a billet, extruding the billet by hot

isostatic pressing and thereafter applying a solution treatment, annealing, cold drawing, etc. to form the core member, inserting said core member into a depression formed in the tip of the matrix made of a Cu-Cr alloy or a Cu-Cr-Zr alloy and combining said core member with the matrix to form an integral mass.

The electrode assembly for use in resistance welding which is recited in claim 7 comprises a pair of electrodes to be set on a resistance spot welding machine, one electrode being a composite electrode comprising a matrix which has a dissimilar electrode material provided integrally in the tip portion which is to make contact with the work, and the other electrode being a single-component electrode. The composite electrode may advantageously use the electrode for use in resistance welding which is recited in claim 5 (see claims 8 - 10).

Embodiments of the Invention

In order to eliminate the aforementioned disadvantages of the prior art, the present inventors conducted various experiments and studies on the constituent materials of electrodes for use in the resistance welding of surface-treated steel sheets. The inventors particularly noted the Cu-based sinter of a mixture of Cu, Cr, Zr, Ag and W powders which they previously proposed in Japanese Patent Public Disclosure No. 210463/1994 and found the following: if the sinter is used as an electrode material in contact with a surface-treated steel sheet, it forms only a small amount of

brittle alloy layer; if the total oxygen content of the powder mixture is reduced below a specified level and if the oxygen present is stabilized as a Zr oxide to reduce the amount of dissolved oxygen, an electrode material can be obtained that is free from the cracking problem, that is less likely to fuse to the work and that has high strength.

The electrode material of the invention for use in resistance welding will now be described specifically. The topics to be first discussed are the criticality of the total oxygen content of the mixture of Cu, Cr, Zr, Ag and W powders, the criticality of the oxygen content of the electrode material, the criticality of the addition of the respective ingredient powders and the preferred ranges of their addition.

Total oxygen in the powder mixture: no more than 500 ppm

In the process of HIP extrusion and the subsequent heat treatments, the oxygen in the powder mixture forms an oxide by binding preferentially with Cr having great affinity for oxygen. Therefore, in the presence of high oxygen content, the precipitation of metallic Cr which should contribute to improved strength decreases, thus making it impossible to achieve a hardness (Hv) of at least 160 at room temperature. The increased Cr oxide has the additional disadvantage of increasing the chance of cracking in the electrode. The major characterizing feature of the electrode material of the invention is that in order to suppress the oxidation of Cr, the powder of Zr which has a greater affinity for oxygen than Cr is incorporated to form a Zr oxide. However, if the total

content of oxygen in the powder mixture exceeds 500 ppm, more than 0.22 wt% of Zr need be added and oxidized Zr will form in an unduly large amount to deteriorate the processability of the powder mixture. Therefore, the total oxygen content of the powder mixture should not exceed 500 ppm.

In order to meet this requirement, powders of low oxygen content have to be used and, in particular, the oxygen content of the major ingredient copper powder has to be reduced. Commercial grades of low-oxygen reduced copper powder contain 200 - 300 ppm of oxygen and using this powder, one can restrict the total oxygen content of the powder mixture to 500 ppm and below. If further reduction of the oxygen content is necessary, the reduced copper powder may be heated (400 - 500°C) in a H₂ gas atmosphere to produce a copper powder with an O₂ content of no more than 100 ppm.

Oxygen in the electrode material: no more than 550 ppm

If the electrode material contains more than 550 ppm of oxygen, more than 0.22 wt% of Zr has to be added and oxidized Zr will form in an unduly large amount to deteriorate the processability of the powder mixture. If the powder mixture does not contain more than 500 ppm of oxygen, a maximum amount of the oxygen that is brought in during the formation of a billet from the powder mixture hermetically sealed in an evacuated copper can is 50 ppm; hence, the content of oxygen in the electrode material (as sintered) can be adjusted not to exceed 550 ppm.

Cr powder: 0.3 - 1.5 wt%

The Cr dissolved as the result of a solution treatment will precipitate as fine-grained metallic Cr in the subsequent precipitation annealing and contributes higher strength. If the addition of a Cr powder is less than 0.3 wt%, the amount of Cr which precipitates in the precipitation annealing is too small to achieve the intended improvement in strength. Even if more than 1.5 wt% of the Cr powder is contained, reduced ductility increases the chance of cracking at the electrode tip when it is urged against the work during welding and this will shorten the electrode life. Therefore, the content of the Cr powder is preferably within the range of 0.3 - 1.5 wt%.
Zr powder: 0.02 - 0.22 wt%

The oxygen in the powder mixture and the oxygen which is brought in when forming a billet from the mixture hermetically sealed in an evacuated copper can will bind preferentially with Cr which has stronger affinity for oxygen; the oxidation of Cr can be suppressed by incorporating the powder of Zr which has stronger affinity for oxygen than Cr and which can be added without causing a substantial drop in electrical conductivity. A maximum amount of the oxygen that is brought in during the formation of a billet from the powder mixture hermetically sealed in an evacuated copper can is 50 ppm and 0.02 wt% of Zr is required to bind with this amount of oxygen; hence, the addition of less than 0.02 wt% of Zr is insufficient to achieve the intended result. On the other hand, 0.22 wt% of Zr is required to bind with 550 ppm of oxygen consisting of 500 ppm which is the upper limit for the

oxygen content in the powder mixture and 50 ppm which is the maximum oxygen content that is brought in during billet formation and adding more Zr is simply a waste. Therefore, the content of the Zr powder is preferably within the range of 0.02 - 0.22 wt%.

Ag powder: 0.01 - 0.5 wt%

Silver and copper form a eutectic at 779°C; hence, by mixing a Ag powder with a Cu powder, sintering can be promoted without deterioration in electrical conductivity and a higher packing density can be obtained. The Ag powder is not sufficiently effective if it is added in an amount of less than 0.01 wt%; on the other hand, beyond 0.5 wt%, the effectiveness of the Ag powder is saturated and the precious Ag powder is simply wasted. Therefore, the content of the Ag powder is preferably within the range of 0.01 - 0.5 wt%.

W powder: 0.1 - 5.0 wt%

Tungsten is a high-melting point metal; not only is it effective in suppressing the diffusion of Zn and the like but it also exhibits high resistance to the wetting with the melt of Zn or other metals, thereby preventing the formation of a brittle alloy layer on the electrode surface. In addition, the electrical conductivity of tungsten is 31% IACS and by far higher than that of ceramics, making tungsten a useful constituent of electrode materials for use in resistance welding. If the addition of tungsten is less than 0.1 wt%, it is not very effective in providing resistance to the wetting with molten metals; beyond 5.0 wt%, not only is the

effectiveness of tungsten saturated but also the difficulties encountered in the processing of electrode chips such as reduced ductility and grindability will increase. Further, the reduced ductility increases the chance of cracking at the electrode tip when it is urged against the work during welding, thereby shortening the electrode life. Therefore, the content of the W powder is preferably within the range of 0.1 - 5.0 wt%.

We now describe specifically the composite electrode of the invention for use in resistance welding and the process for its manufacture with reference to Fig. 1.

(Core member) First, a deoxidized copper can is filled with a mixture of Cu, Cr, Zr, Ag and W powders, fitted with a copper lid by TIG welding and evacuated through a degassing tube on the copper lid, which is closed hermetically by TIG welding to form a billet. Then, the billet is homogenized at 950°C for 1 h, HIP extruded at 850°C, heat treated at 950°C for 1 h, subsequently quenched in water to effect a solution treatment and subjected to more than one cycle of annealing and cold drawing operations. The produced sinter is cut to a specified length and ground to make a core member 1.

(Fitting the core into a matrix) A Cu-Cr or Cu-Cr-Zr alloy is forged to form a matrix 2 having a hole 2a at the tip into which the core member 1 is to be fitted; then, cold forging is performed to press the core member 1 into the hole 2a while forming a hole 2b in the bottom through which cooling water is

to flow; subsequently, the tip is ground to the desired shape, thereby completing a composite electrode.

The manufacture of the composite electrode requires the additional step of making the core member an integral part of the matrix before the finishing step to obtain the desired electrode shape. Yet the total number of processing steps involved is much smaller than in the case of a single-component electrode which is solely composed of the constituent material of the core member. In the manufacture of the composite electrode, the processing of a billet requires the largest number of steps; since the core member has a smaller diameter (e.g. 6 mm) than the matrix (e.g. 16 mm), the number of core members having a diameter of 6 mm that can be drawn from a single billet is about 7 times as great as the number of single-component electrodes having a diameter of 16 mm that can be drawn from the same billet. In other words, the billets that are required to fabricate a given number of single-component electrodes solely composed of the constituent material of the core member are 7 times as many as the billets that are required to fabricate the same number of composite electrodes. Therefore, the composite electrode which has the core member embedded as an integral part of the matrix by cold forging can be produced through a significantly reduced number of steps. As a further advantage, by combining the expensive core member with the economical matrix integrally, one can produce an economical and long-lived electrode material.

In the next place, we will briefly describe the electrode assembly of the invention for use in resistance welding which comprises a pair of electrodes that are to be set on a resistance spot welding machine. As already mentioned in the "Problems to be Solved by the Invention", if resistance spot welding is to be performed on surface-treated steel sheets clamped between an electrode having a domed or frustoconical tip with a small radius of curvature and an electrode having a tip with an increased radius of curvature or a flat tip, fusions or shunt marks occur on the side where the electrode having a tip with an increased radius of curvature or a flat tip is placed even if both electrodes are of a composite type which has high resistance to fusion. This would be because the core member of the composite electrode has a slightly different electrical conductivity than the matrix, so that during welding, the current flowing paths do not concentrate sufficiently in the core member to prevent the occurrence of fusions or shunt marks.

One possible way to solve this problem is using a single-component electrode as one member of the electrode assembly. However, it is costly to form the single-component electrode from a sintered powder. On the other hand, if a conventional chromium-copper alloy is used to make the single-component electrode, there will be not disruptions in the current flowing paths but the welding current concentrates in the center of the electrode to reduce the occurrence of fusions and shunt marks. Thus, by using a composite electrode with a

domed or frustoconical tip which is resistant to fusion and a single-component (e.g. chromium-copper alloy) electrode having a tip with an increased radius of curvature or a flat tip, the occurrence of fusions, sputtering and shunt marks can be reduced, with the added advantage of reduced cost.

Examples

The present invention will now be described in greater detail with reference to Example 1 which corresponds to claims 1 - 6 and Example 2 corresponding to claims 7 - 10.

Example 1

Powder mixtures (Run Nos. 1 - 3) having the compositions shown in Table 1 were packed into deoxidized copper cans (i.d. 131 mm; o.d. 143 mm), which were evacuated and hermetically sealed by TIG welding, heated at 950°C for 1 h and HIP extruded at 850°C to produce bars. The bars were heat treated at 950°C for 1 h, quenched in water to perform a solution treatment, drawn into a smaller diameter (13 mm) and annealed at 425°C for 5 h. Upon further drawing, core members having an outside diameter of 6.1 mm were produced.

Table 1

Run No.	Core composition, wt%							Matrix composition, wt%	
		Cu	Cr	Zr	Ag	W	O, ppm	Cu	Cr
Example	1	bal.	1.2	0.2	0.1	1.6	430	bal.	1.3
	2	bal.	1.2	0.12	0.1	1.6	200	bal.	1.3
	3	bal.	1.2	0.30	0.1	1.6	3300	bal.	1.3
Comp. Example	4	Cu-1.3 wt% Cr							
	5	Cu-0.3 wt% Al ₂ O ₃							

Round bars (16 mm ϕ) made of a Cu-1.3 wt% Cr alloy were cold worked to form a depression 2a (6 mm ϕ) in the center as shown in Fig. 1. The core member 1 was inserted into the depression 2a by cold working so that the core member 1 became an integral part of the matrix 2. Each of the combinations thus prepared was subjected to a resistance welding test after it was worked to an electrode chip with a cooling hole; the chip had an outside diameter of 16 mm, a tip radius of 8 mm, a tip curvature radius of 40 mm, and a length of 25 mm. Two comparative samples (Run-Nos. 4 and 5) were fabricated as single-component electrode chips made from a commercial chromium-copper alloy (Cu-1.3 wt% Cr) and 0.3 wt% Al₂O₃ dispersed copper.

Using the five electrode chip samples, two galvanized steel sheets (0.8 mm^t) were joined by resistance welding. When the diameter of the weld nugget became smaller than a minimal value for the class of JIS Z 3140 (3.8 mm^t), the number of spots that had been produced was taken as the life of the

spots that had been produced was taken as the life of the particular electrode. The welding machine was of a single-phase ac type. The welding conditions were as follows: welding current, 10 kA; clamp force, 2.5 kN. The test results are shown in Table 2, which also show the Vickers hardness and electrical conductivity of each electrode sample.

Table 2

Run No.		Core		Matrix		Electrode life (No. of spots)
		hardness (Hv)	conductivity (%IACS)	hardness (Hv)	conductivity (%IACS)	
Example	1	160	83	167	80	5300
	2	148	85	168	80	5500
Comp. Example	3	161	70	167	80	3500
	4	hardness(Hv); 160; conductivity, 80% IACS				2500
	5	hardness(Hv); 150; conductivity, 87% IACS				3000

Looking at Table 2, one can see that the electrodes of Run Nos. 4 and 5 were short-lived since they were prone to fuse to the work. The electrode of Run No. 3 was also short-lived since the Cr particles oxidized due to the high oxygen concentration and cracking occurred in the microscopic structure. In contrast, Run Nos. 1 and 2 which were examples of the invention satisfied the requirement for the total oxygen content not exceeding 500 ppm; hence, they were free from Cr oxidation and internal cracking, resistant to the fusion to the surface-treated steel sheets and much longer lived than the comparative samples (Run Nos. 3 - 5).

Example 2

Electrode samples having the compositions shown in Table 3 were subjected to a resistance welding test. The composite electrodes consisted of a Cu-1.0 wt% Cr matrix having an outside diameter of 16 mm and a Cu-1.2 wt% Cr-0.2 wt% Zr-0.1 wt% Ag-1.6 wt% W core member having an outside diameter of 6 mm which was inserted into the center of the matrix to form an integral mass. The core member was prepared and made an integral part of the matrix by the same methods as employed in Example 1.

Table 3

Run No.		Upper electrode composition, wt%		Lower electrode composition, wt%	
		core	matrix	core	matrix
Example	6	Cu-1.2Cr-0.2Zr-0.1Ag-1.6W 0:430 ppm	Cu-1.0Cr	Cu-1.0Cr	
Comp. Example	7	Cu-1.2Cr-0.2Zr-0.1Ag-1.6W 0:430 ppm	Cu-1.0Cr	Cu-1.2Cr-0.2Zr-0.1Ag-1.6W 0:430 ppm	Cu-1.0Cr
	8	Cu-1.0Cr		Cu-1.0Cr	

The moving upper electrode 3 (see Fig. 2) and the fixed lower electrode 4 (also see Fig. 2) were placed on opposite sides of the work according to the combinations shown in Table 3. The upper electrode chip had an outside diameter of 16 mm, a tip curvature radius of 40 mm and a length of 25 mm; the lower electrode chip had an outside diameter of 16 mm, a flat tip and a length of 25 mm; both chips had a cooling hole

through which cooling water flowed. The workpieces were two galvanized steel sheets 5 having a thickness of 0.8 mm, which were clamped together and subjected to resistance welding; the numbers of occurrence of fusions, sparks and shunt marks were measured and their incidence was determined. The welding machine was of a stand-alone single-phase ac type. The welding conditions were as follows: welding current, 10 kA; weld time, 12 cycles; clamp force, 1.96 kN. The test results are shown in Table 4.

Table 4

Run No.			Light fusion		Spark		Shunt mark	
			No. of occurrence	total	No. of occurrence	total	No. of occurrence	total
Example	6	upper	0	12	11	11	0	0
		lower	12	(2.4%)	0	(2.2%)	0	(0%)
Comp. Example	7	upper	0	30	8	11	0	10
		lower	20	(4%)	3	(2.2%)	10	(2%)
	8	upper	26	36	45	45	0	0
		lower	10	(7.2%)	0	(9%)	0	(0%)

Sample No. 7 had slightly different electrical conductivities in the core member and the matrix and, therefore, during welding the current flowing paths did not concentrate in the center, thereby causing fusions and shunt marks. Sample No. 8 which was solely composed of the chromium-copper alloy had a tendency to fuse to the galvanized

steel sheet and formed a brittle alloy layer at the tip of the upper electrode, which hence was subjected to great wear and tear in service; during the application of an electric current, local heat generation occurred to cause many sparks. In contrast, sample No. 6 which was within the scope of the invention used the fusion-resistance composite electrode as the domed upper electrode while placing the chromium-copper electrode as the flat lower electrode, thereby successfully reducing the occurrence of fusions, sputtering and shunt marks.

Advantages of the Invention

As described above, the electrode material of the invention for use in resistance welding does not form a brittle alloy layer on the surface, does not crack and will not easily fuse to surface-treated steel sheets; therefore, it has the outstanding advantage of markedly increasing the life of an electrode being used in the resistance welding of surface-treated steel sheets. The process of the invention for producing the electrode for use in resistance welding adopts the step of embedding an electrode tip in the matrix by cold forging and this offers the significant advantage of greatly reducing the number of manufacturing steps involved. In addition, the process is industrially feasible since an increased number of core members can be produced simultaneously by a single cycle of HIP extrusion. Further in addition, the electrode assembly of the invention for use in resistance welding, which comprises a pair of electrodes to be

set on a resistance spot welding machine, has the advantage of not disrupting current flowing paths, reducing the occurrence of fusions, sputtering and shunt marks and hence being serviceable for an extended period of resistance welding of surface-treated steel sheets.

Brief Description of the Drawings:

Fig. 1 shows schematically the process for producing the composite electrode of the invention; and

Fig. 2 shows schematically the sharps of the electrodes used in Example 2 and their placement.

Key to Symbols:

1 ... core member; 2 ... matrix.